Introduction to Simulation Analysis of Space Shuttle Manifest Options

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PH-M3

Discrete Event Simulation

- "Discrete-event simulation is the modeling of a system as it evolves over time by a representation in which the state variables change instantaneously at separate points in time." Law and Kelton, *Simulation Modeling and Analysis*.
  - For example, in a shuttle manifest model, a state variable could be the location of the orbiter.
    - Location might initially be the OPF. At some future point in time, the orbiter will change from being in the OPF to being in transit to the VAB. Likewise, it will then arrive at the VAB at some later point in the future.
- Discrete-event simulation modeling constructs enable a wide variety of systems to be modeled. Basic constructs include:
  - seize a resource;
  - process for some length of time;
  - Release resource;
  - decision nodes,
  - route to specified location,
  - etc.

Applicable to Modeling Shuttle Manifests

- Discrete Event Simulation, (may also be called Monte Carlo simulation) is an appropriate tool for modeling shuttle manifests.
  - Allows us to capture the inherent complexities of implementing space shuttle manifests.
    - Added work content growth in the OPF, VAB, or launch pad etc.
    - Schedule delays to Orbiter, ET, RSRM, and SRB etc, caused by PRACA.
    - Launch delays caused by weather or technical problems
    - Dryden landings
  - Provides a quantitative measure for our ability to achieve future launches.
  - Enables sensitivity analysis on the system and answers “What-if” type of questions concerning the influence of input parameters.
    - Manifest planned work days and margin days in the OPF, VAB, Launch Pad.
    - Number of launch pads, flight hardware assets, launch restrictions.

Discrete Event Simulation Analysis Performed in 2003

- Node-2 Launch Date Assessment Model (January).
  - Provided a quantitative assessment of the likelihood that NODE-2 will launch on February 19, 2004 or subsequent dates.
  - Provide Shuttle Program with a tool for assessing how proposed changes increase or decrease ability to achieve the NODE-2 launch date.
  - Identified ways to increase probability of achieving planned NODE-2 launch.
  - Presented to Space Shuttle Program Manager.
- SSME Engine Analysis Model (Summer/Fall)
  - Showed the influence of SSME fleet size on average annual flight rate.
  - Presented to Space Shuttle Program Manager.
- Launch Window Launch Probability Model (October)
  - Determined the launch probability for various launch window durations e.g. 3-day versus 5-day.
  - Presented to Space Shuttle Flight Operations and Integration Office.
- Comparison of Two Manifest Options (November)
  - Analyzed likely HST Launch date given two different manifest option each having the same launch date.

Manifest Analysis Process.vsd

Simulation Modeling and Analysis of Space Shuttle Manifest Options

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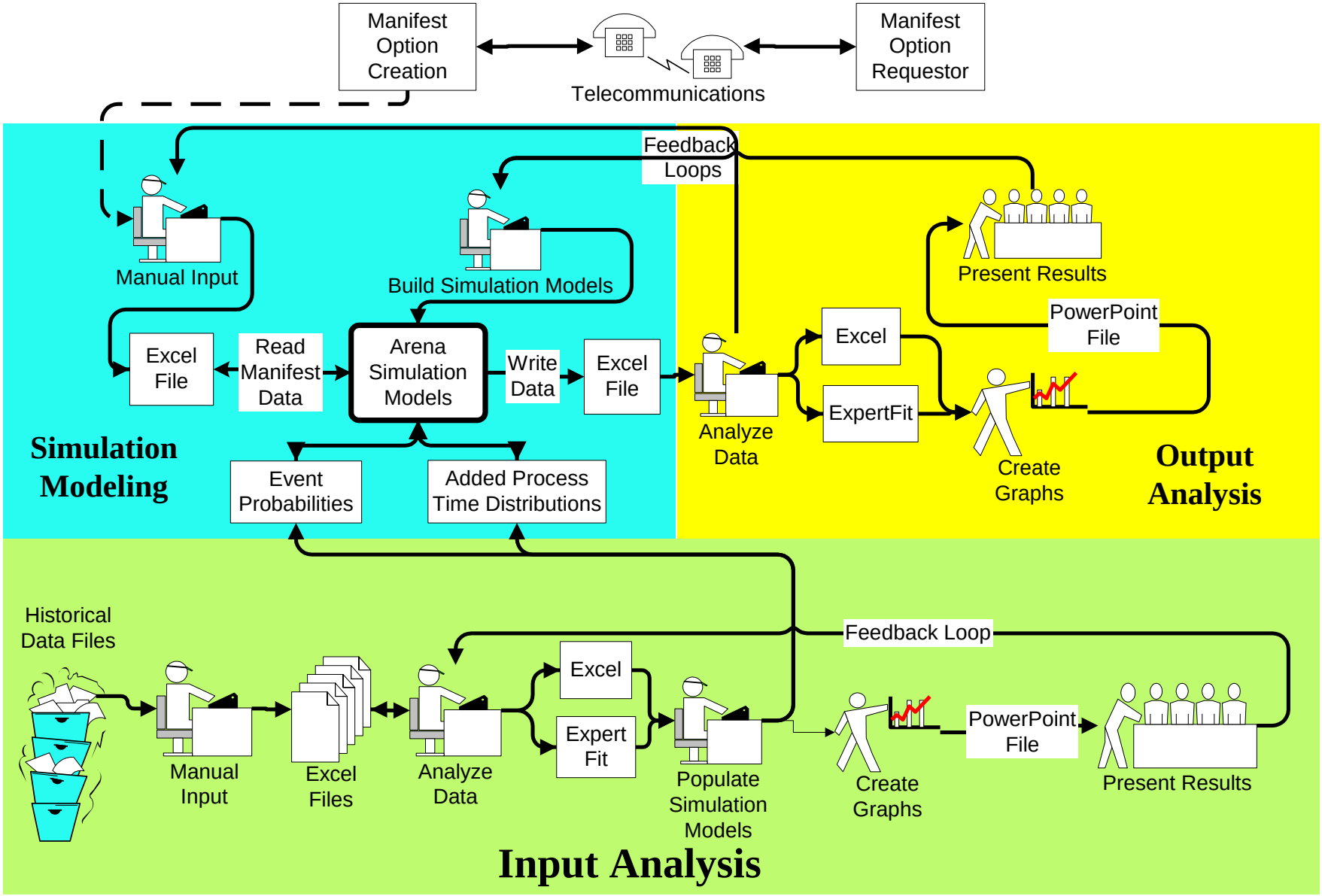
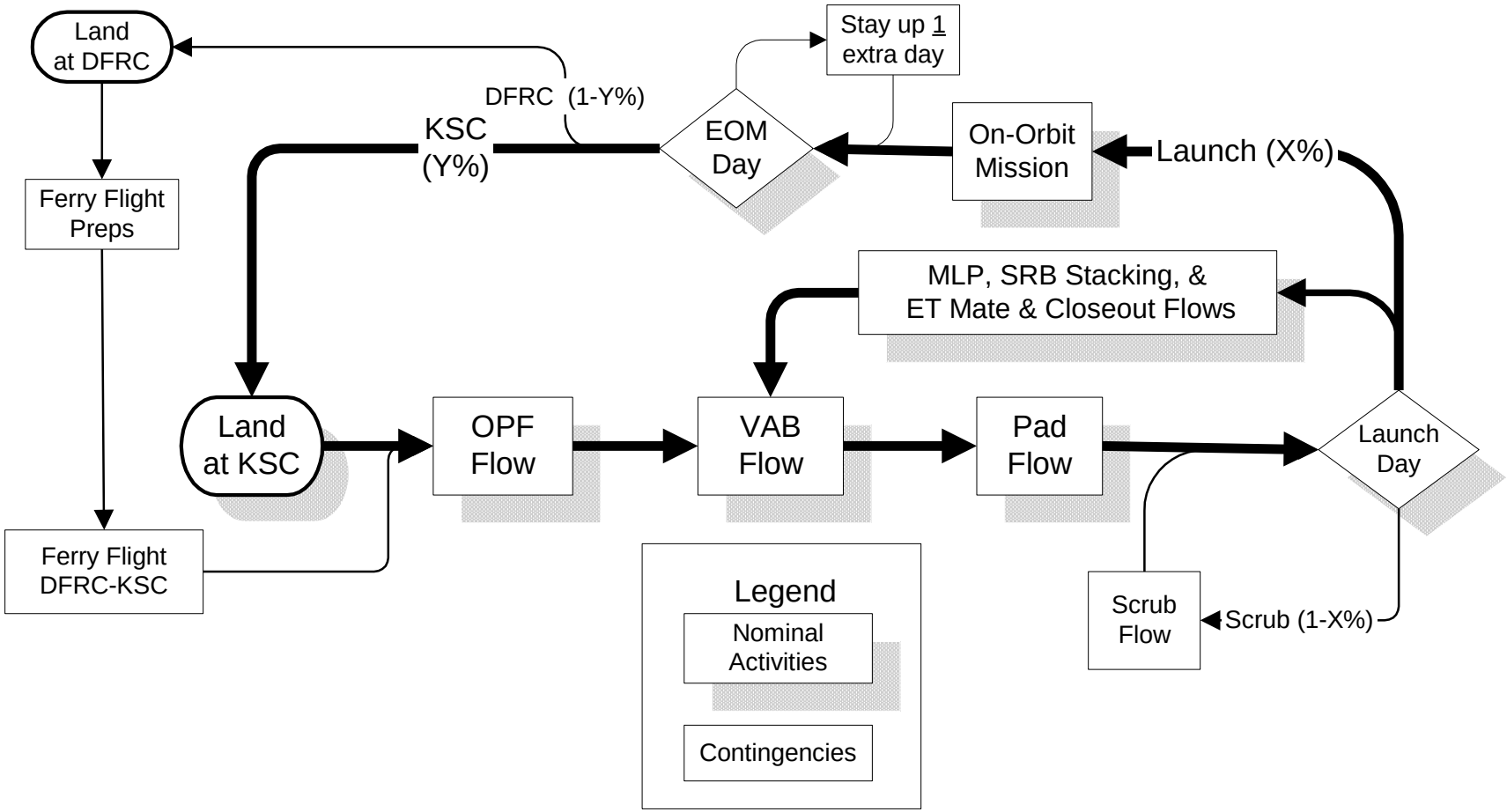
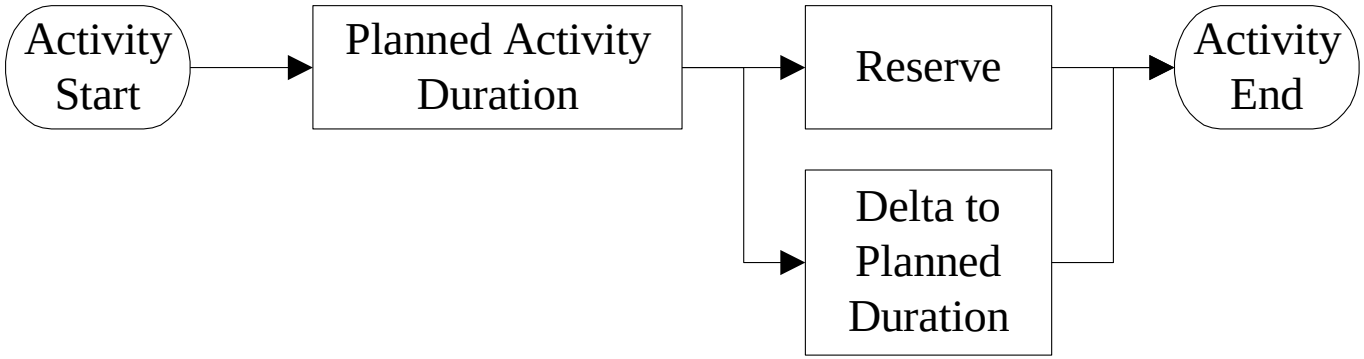


Shuttle Flight Hardware Processing Model

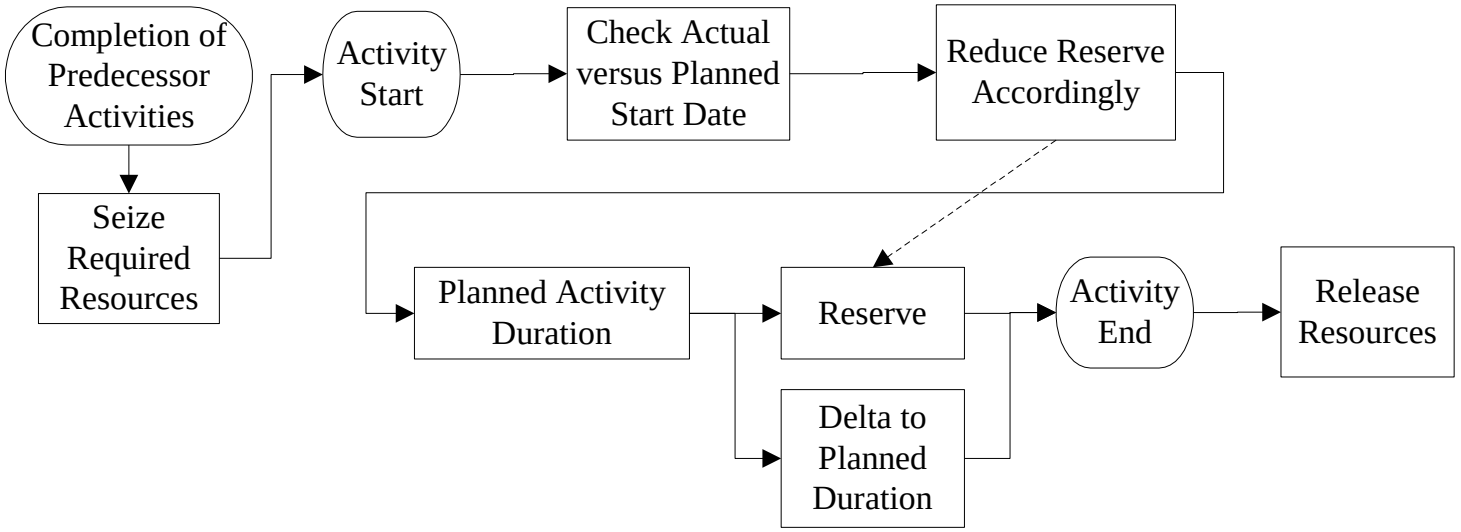


Flow (OPF, VAB, Pad) Modeling Constructs

- Activities, such as OPF, VAB, and Pad flows, are modeled as a combination of the planned activity duration, reserve, and delta to planned duration, as shown by the figure below.
  - The planned activity duration and available reserve are inputs from the particular manifest being modeled.
  - The delta to the planned duration is based on history.
  - During simulation runs, as in real shuttle processing, if the delta to the planned duration can be absorbed by the reserve, then the activity will finish on schedule. However, if the delta exceeds the reserve, then the activity will complete late.



Flow (OPF, VAB, Pad) Modeling Constructs (cont)



- The simulation logic includes checking for completion of predecessor activities and availability of required resources.
- The simulation logic automatically reduces reserve if the activity starts late.

Input Analysis and Simulation Results

- A detailed briefing on input analysis for shuttle manifest simulation models is available in a separate presentation.
- Simulation results for specific simulation models are available in separate presentations.